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A LECTURE

Delivered at the Infirmary for Nervous Diseases, May 17, 1888.

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PHYSICIAN TO THE INFIRMARY

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IT has long been my wish to give in this hospital a series of lectures on certain symptoms of nervous diseases. This would have included what I may call their natural history—the modifications they exhibit in various diseases and in different people. Circumstances will interfere with the full development of my project, and I shall this May be able to give but one lecture. For this I have chosen muscular reactions in health and in disease, and, limiting our study to mechanical stimuli, I shall have little to say as to electricity.

There are symptoms which exist in health and are changed or abolished by disease. There are reactions known only to disease. Most of the muscular reactions are present in the healthy, and are merely altered by sickness. I have selected them for treatment in this lecture because a full enough statement of recently acquired knowledge as to them is not to be found in the text-books, and because with the material in our wards it is easy to illustrate my subject.

These symptoms, which are also facts of health, in-

clude what results we get from striking a tendon, and those which follow a blow on the muscular tissue.[1]

If the tendon of a muscle be abruptly pulled upon, the like effect is conveyed through it to the muscle and this responds by a contraction, which in turn pulls on the tendon and moves the connected part. In certain morbid states any muscle can be made to react to a blow on its tendon, but in health, with less sensitiveness of muscular reply, only favorably situated tendons can be so used with certainty of response. The tendon must span some region of soft tissue, so that being struck while tense, it may be driven down in a loop, and thus occasion a quick jerk of the muscle. The lower tendon of the patella and that of the gastrocnemius are best situated; the biceps at the elbow, not quite so favorably; and the temporals reply to a blow on the lower jaw.[2]

Tendon-jerks may be had elsewhere even in health, but care is needed, and peculiar forms of hammer. Indeed, for accurate study of any tendon-jerk the hammer with a head of not too hard caoutchouc is desirable. Dr. J. M. Taylor has devised the one I show you, the long side for use on tendons, and the round end to get muscle responses by a direct blow on the muscle (Fig. 1).

It will be easiest and best to begin with the study of the knee-jerk or knee-phenomenon, as that was the first of its class to be clinically utilized, the one best known, and most fully studied.

Let us see, in a normal man, how readily to evoke knee-jerk, or what we briefly call K. J.; how to measure it; what modifies it; how to explain it and its variations; and, lastly, what clinical value it has. When we have covered this ground as to knee-jerk, the other like phenomena will demand little additional explanation.

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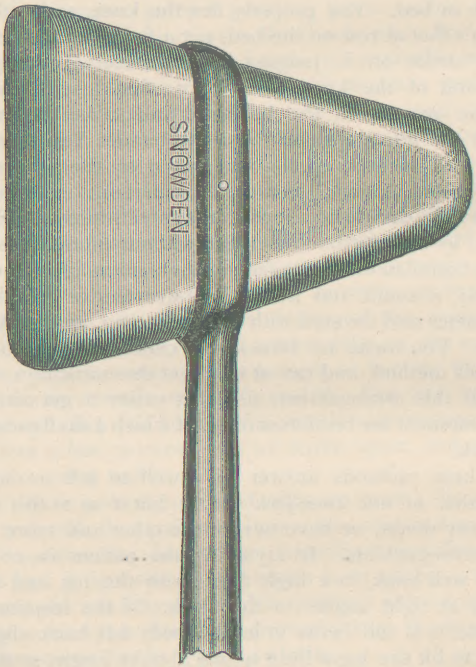
1 For the best account of them see Buzzard's admirable essays, and Ross, p. 162, vol. i.

2 First discovered in this hospital by Dr. Morris J. Lewis.

To test roughly the mere presence of knee-jerk, it suffices to set the patient on a table's edge, so that the legs may swing, or to let him cross his legs so as to allow the upper limb to hang passive. Then strike, with the side

Fig. 1.



Taylor's hammer.

of the palm, on the tendon of the knee-cap above its tibial attachment, a smart, quick blow. The tendon thus abruptly jerked communicates its motion to the muscle, and this responds in mass by a contraction which moves

the leg and foot. A prettier way is to put the left forefinger on the tendon, and then to strike with the other hand, or, better, with the hammer, upon the finger so placed. The faintest response is felt by the finger while the eye may observe also the lift of the foot.

This plan is very useful for examining a man on his back in bed. You properly flex the knee, and with the man's foot at rest on the bed, put a finger on the tendon and strike on it, judging by the sense of touch the amount of the knee-jerk. Very often I seize the extensor mass with the left hand and strike the tendon with the ulnar edge of the right hand. You thus feel the muscle as it swells responsive to the jerk made through its tendon. In rapid examinations, in women, it is usually easy to decide as to the mere presence of knee-jerk, by striking on the finger without lifting the skirts. The best plan of all is to feel for the tendon, place thereon firmly a small rod about three-quarters of an inch in diameter and covered with rubber tubing, and strike on this. You waste no blows and cause less pain by use of this method, and can at once get the maximum effect, With this arrangement, also, it is easier to get correctly the moment for reinforcements, of which I shall presently speak.

These methods answer very well to tell us simply whether or not knee-jerk exists; but if as to this there be any doubt, we have to resort to other and more careful arrangements. In my clinic, the patient sits at ease, and well back, in a high chair, with the leg and body both at right angles to the thigh. If the response be feeble, it is still better to let the body fall back slightly, and to lift the leg a little above a right angle, so that it rests quite passive. You thus stretch the whole muscle from above and from below before you strike.

It is sometimes hard to make a patient entirely passive, and this passivity, some of the books say, is essential; but a man cannot entirely stop or conceal the knee-jerk

response, be he ever so nervous or unable to relax his muscles. *Violent* innervation of the crural nerve will stop it, but milder effort will not.

The books tell you to seat the patient on a table without back support for this examination, but, as I shall soon point out, there is reason in doubtful cases for securing a more passive position, since motion elsewhere unnaturally increases the knee-jerk. For very delicate studies, like those in Lombard's admirable essay, he puts the patient on one side, the leg in a guttered splint, the foot suspended in a stirrup by a long string. Thus placed, the leg moved easily in response to the knee-jerk. In our own researches, a variety of positions were employed. In common practice the crossed leg answers, but if there be doubt as to whether the knee-jerk is either above or below the normal standard, certain precautions must be taken to insure accuracy. The need for such care will be seen as we go on to study what I like to call the natural history of this symptom. Let us observe it. As the hammer falls on the tendon of my patient, at ease on the lounge, or leaning back in a chair, the muscle contracts and the foot and leg are lifted and then fall back. We see that the excursion of the foot is less or more. As we strike again, and again, this excursion varies.

In some normal men, and often in spastic disorders, the jerk calls the opponents into action, and as Lombard shows, when the foot swings laterally suspended, and thus free, it does not always return to its place, as if the muscle did not fully relax. The primary jerk varies, but there is always a maximum beyond which the foot does not go, no matter how hard we strike.

Let us further study the influence of position; I lessen the angle of the leg to the thigh, and, as you see, the repeated blows on the tendon get slighter and slighter responses. A very able observer (Gowers) thinks this is due to the fact that tension is physiologically essential to

the evolution of knee-jerk. As to this, I think him mistaken.

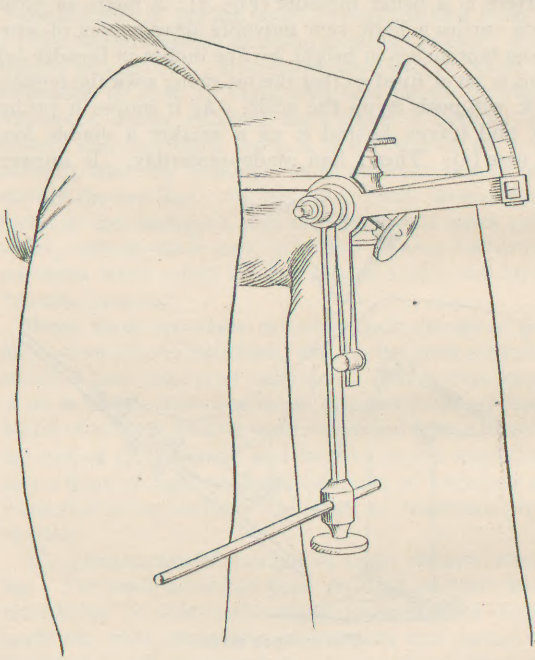
It is only mechanically essential (and under certain conditions it is not required at all). The tension enables us to act sharply on the largest mass of muscle. Tension is convenient for this reason. I showed long ago that a certain amount of tension, even in spastic cases, causes knee-jerk to cease. To show this, I place a spastic patient on his belly, and with the knee at a right angle, continue to strike the tendon as I further flex the limb. At a certain point the knee-jerk ceases. This is not (as you might suspect) merely because the tendon is at a disadvantage, mechanically, on account of extreme flexion, as may be easily shown, and very prettily.

The subject is seated, and the knee held at nearly that limit of flexion which stops knee-jerk; as you see, we get fair replies. Then the man is allowed to fall back supine, and the tension thus added at the truncal end of the muscle, stops all knee-jerk. You may now see why we are careful as to position, both of body and of leg.

To get the best results out of knee-jerk, a little practice is needed. If we desire greater accuracy in our record than merely to be able to say knee-jerk present in excess or not, we have here, for clinical use, my friend Dr. Warren Lombard's simple meter. The instrument, as I now show it to you, will probably be used by neurologists only. A strong clamp attaches the instrument to a chair raised so as to keep the patient's legs off the floor. A bar which projects between the patient's legs, and which can be pulled out or shortened, carries a dial plate divided into centimetres. A light swinging rod, with a cross bar, is set so as to drop on to the middle of the tibia. The patient sits back at ease; the blow on the tendon is struck; the rising leg lifts the rod, and this carries before it an index which it leaves so as to mark the limit reached. Two or three blows give us the maximum, and then we go on to get, also, the maximum reinforcement.

Should this instrument come into use, it would be well to agree on a common method of dividing the dial, and on a common length of lever.

FIG. 2.



Lombard's meter.

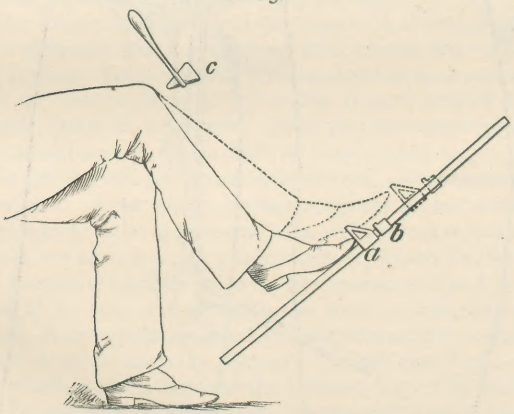
Dr. Lombard's ingenious instrument, which is too costly for common use, set me to thinking how more easily to get a numerical statement of knee-jerk for reference.

With the patient always in the same position, with care

to avoid reinforcements, place a yardstick or metre against the wall, in front of the foot, so that some one else can note the height to which the tip of the foot rises ; get the maximum from several blows on the tendon, and note it for future use.

Here is a better measure (Fig. 3) : A metre or yard-stick carries a light, very movable arrangement of wire, about four inches in height, by five inches in breadth (*a*). This is set or fixed so that the toe rising with the tendon-jerk, will push it up the scale. As it moves it pushes up, and leaves behind it as a marker a double loop of wire (*b*). This I had made yesterday. It answers

FIG. 3.



The author's meter.

admirably, and in a little more complicated form will do still better. Needless to insist that the results may not be generally comparable, but, in a measure, they may be, and, for comparison, from time to time, in individual cases, are most desirable.

Our object is, of course, to get a normal expression of the knee jerk. As we avoid, therefore, too great or too slight flexion, so also do we avoid all other influential agencies. Thus, if it did not take too long, you might easily be made to see that pressure on the sciatic nerve, —constriction of the leg (even so slight as that made by a rolled-up pantaloon) serves to lessen knee-jerk. Even fatigue may do this. In my own case, and in others, the knee-jerk is least at night and best in the morning. Moreover, damp, relaxing days lessen it notably, and always after my winter work it is not so good as in the autumn after my holiday. It is different also in most men in the two legs. On the other hand, several things increase the knee-jerk, and may cause it to seem great, when, without such aids, it is not. These influencing additions were called by Dr. Morris Lewis and myself "reinforcements."

What these are—how to avoid their deceptive presence—how also to use them, will be the next subject to which I now ask your attention. About this matter more is known than was at our disposal three years ago. Much of what *is* known was contributed by members of the staff of this hospital, and the four papers which have cast a flood of light on the phenomena of knee-jerk are, I am glad to say, entirely the work of American physiologists.

The germination of thought in crops is often interesting. For years there had been no large addition to our knowledge of knee-jerk, when Jendrássik of Prague made the most interesting observation that certain *violent* motor acts increased the knee-jerk, if they took place in time nearly coincident with it. That he should have here left this fruitful fact without further study seems amazing. Still more that it should have remained for some years almost unnoticed.

Turn with me now to the normal subject before us, and let us illustrate the strange harvest which, for Dr.

Lewis and for me, grew out of Jendrássik's pregnant observation. I shall show that every motion, if at all decided (even if it involve a small single muscle), increases knee-jerk. To wink, speak, cough, move a finger is enough, as you see. Probably all coincident motions thus reinforce knee-jerk in degrees which vary with their intensity. A vast range of facts in these directions was evolved by us out of Jendrássik's single statement. Just now they interest us on but one side. Presently we may discuss their cause. Enough at present to show that they teach us two things. First—that when a knee-jerk is seemingly absent an added motor reinforcement may show it to be not entirely lost. Second —that in estimating normal, or other knee-jerks, if we desire accuracy, the patient must be at rest with closed eyes, and neither speak, nor laugh, nor swallow, nor make any avoidable movement.

But while we were thus enormously adding to the singular fact made known by Jendrássik, we discovered a new set of reinforcing agencies. Just as it seemed that all voluntary motion apparently increased knee-jerk, so also, we found that a vast range of sensations had the same power. This discovery has, as yet, been of no direct clinical value. It has, however, been shown by us of late that in certain cases, motor reinforcements fail to act, and sensory reinforcements remain efficient. In others the reverse obtains, and it is to be hoped that as we get clear ideas as to the spinal tracks of reinforcements such knowledge as this may become valuable.

To exhibit an illustration of sensory reinforcements, I strike the tendon lightly, so as to cause a gentle foot movement. Just before the next blow I touch the skin anywhere, on the arm, neck or leg, with ice or a hot blade, or pull a hair or pinch the skin. The results as seen are startling. There seems to be a minimum limit of sensory reinforcement. A touch does not answer, or seems not to do so, and yet, probably all sensory im-

pressions, like all motions, act in this direction. Not all, however, have power visibly to represent their effects. The most tremendous influence is to be had by passing galvanism through the anterior part of the brain, and if we add to this consentaneously also a sensory and a motor reinforcement we get such knee-jerks as elsewhere are seen only in spastic disease. Galvanism, thus used, has probably a complex effect, made up of sensation, motion, emotion, and some other more immediate affections of the brain.

In practice I find you can get the united influence of sensory and motor reinforcements by asking a man to pinch his arm at a signal; if, then, also he should make a grimace, you will have powerful reinforcements of two kinds.

When you come to suspect that a diseased zone of cord may probably reinforce parts below it, such sensory increments become most interesting to think of.

But let us turn, for the time, to the next crop evolved by the work of Lewis and myself. My friend Dr. Warren J. Lombard took up the subject, and with accurate laboratory methods, confirmed all of our results, and added many things of interest. He showed, as we had done, how fatigue of body lessens knee-jerk, how sleep affects it, and how the weather influences it. We come to see, as we read these two papers, that this responsive act represents well the state of the body. For reasons to be later stated, it is as yet clinically valueless in this direction, because of its too delicate cognizance of actions, sensations, and emotions. Indeed, the most brilliant discovery of Lombard was that "emotion enormously affected the knee-jerk." If you listen to music, or read poetry and a passage touches you, the knee-jerk obtained just then is vastly reinforced. A cry of a child, a sudden knock at the door suffices to do the like. And all this is to be remembered, because it gives some clew to the mechanism of reinforcements, and because of the influ-

ences of emotion in cases examined, especially for the first time. In fact, emotion seems to be, of all reinforcements, the most remarkable, save galvanism of the head. When, for example, you have before you an hysterical girl, what with fear, excitement, apprehension, and perhaps shame, there is an emotional state which seems strangely competent to exaggerate the knee-jerk, and to do so for some considerable time, making what I might call a quasi-permanent state of reinforcement.

In Lombard's experiments it was brief, transient emotions which were thus active, and he was not called upon to see, as we are, the whole spinal system thus excited for half an hour or more by the grouped excitatory power of many emotions. Every neurologist sees this condition. You strike the knee in an hysterical girl and the knee-jerk is surprising, and with it often enough the other leg flies up, and one arm—usually the left. A blow on the tibia will not do this as a blow on the tendon does. It is a combined result of a blow on the tendon and of emotion.

We see the same thing in the first examination of neurasthenic, timid and apprehensive men. At another visit, the exaggeration is missing. It has gone with the subsidence of emotion, or has much lessened.

I have enumerated most of the known agencies which lessen or increase knee-jerk. There may be many others, and Lombard's study and our own show that in all likelihood the interior operations of the body, and even of the mind, may furnish reinforcing agencies which we have no means of analyzing or explaining.

I have dealt thus far only with the natural history of the evolved symptoms of knee-jerk. What, now, is the explanation of this occurrence?

All muscles have a certain capacity to respond by motion to the two means of excitation known to us. These are, first, mechanical, as a blow, or a sudden pull

on the muscles through the tendon; and, second, the various forms of electricity.

Let us deal with the first. I strike a blow on the tendon of the patella below the knee. The crural mass of muscle answers by motion. Again, I strike just above the patella—we are still on tendon—and the muscle moves in mass. I go higher, and the extent of the movement lessens as I leave the tendon. Now, I turn my hammer, and strike with the point on the muscle. There is still motion, but it is limited in amount, and as to the area affected. On the thin chest muscles, with bone beneath them, you see best what occurs. The blow falls; a certain length of fibre shortens, and in some cases, and always in certain situations, just under the hammer a hump of muscle rises slowly, and as slowly falls away. If all at once you could strike every fibre of the muscle, you would have a result in effect like that which the favoring relation of muscle to tendon enables you to get when you strike the latter. So far the two sets of motor responses are much alike; also, there is a further resemblance. Both are reinforcible by distant motion and by sensation. Strike lightly with the rounded hammer point on the supinator longus, and at the next blow tell the patient to shut the other hand strongly, and you get a visible reinforcement.

How, then, do they differ? Both involve primarily the presence of that intrinsic irritability which all muscle possesses. If disease or injury severs the motor or sensory nerve of a muscle, or damages its related spinal centre, the tendon-jerk ceases, but the muscle-jerk from a direct blow remains. The inference is that the spinal cord contributes something, which, by adding to the responsive capacity of the muscle, enables it to move in reply to the pull made on its tendon. The direct muscle blow still causes motion, and whether this response be, in a measure, *lessened* by such nerve or spinal paralysis

as *destroys* tendon-jerk, is yet to be learned.[1] The same elements may be needed for the *full* reply to both forms of stimulus, but the direct blow is what I may call a more positive stimulus than the tendon-pull, and so evokes a reply from the intrinsic unassisted muscle quality of excitability. This property of muscle may even be increased by disease which destroys the knee-jerk. The nerve or spinal loss which acts thus destroys for both tendon-jerk and muscle-jerk the capacity to be reinforced by distant motion or sensation, so that here, too, is an added resemblance between muscle-jerk and knee-jerk.

And now as to the mechanism, which, in health, causes a muscle stretched abruptly through its tendon to contract. The mere intrinsic muscular irritability will not suffice. That gives the muscle power to contract under a blow, or from electricity, but something more is wanted to give rise to the response to a pull. What is the addition which supplies this excess of excitability? Whatever it be is present in excess during reinforcements, and whatever explains the mere knee-jerk must also, in a measure, explain reinforcements.

We are thus brought to the much disputed question as to whether knee-jerk be a direct muscle act or a reflex. At first, it seemed simple to suppose it a reflex from the tendon, but when all tendon nerves are cut it still occurs. Then it was presumed to be a reflex, due to the sensory effect of the multiple pulls on the nerves of the muscular aponeurosis, through the tendon. This was supposed

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[1] Thus, if we conceive that both a direct blow and tendon-pull act alike, and both profit by the spinal aid, this latter being taken away destroys the tendon-jerk, but leaves us able to see a muscle-jerk, because, even if this loses something by loss of spinal connection, the mere intrinsic muscle properties enable violent local stimulation to get responses. To prove that something is thus lost, for it is but theory, we have yet to study the facts with more care.

to cause excitation of the spinal cord, an efferent motor response ending in a muscle act. This would be an ordinary reflex act. But, as against this, was the fact that the time of a tendon-jerk is not less than a fourth that of a common skin reflex. This objection seemed final to most physiologists as against the reflex theory. And yet, some spinal aid was clearly requisite. An able English neurologist (Gowers), deceived, as I think, by the mechanical needs of the knee-jerk, came to believe that tension was the precedent requisite, and that preparatory passive tension, obtained by flexion, excites by a reflex influence a state of extreme irritability to local stimulation which enables knee-jerk to occur. In other words, there is a precursory tuning of the muscle.

My previous remarks show that tension is less needed than Gowers supposed; and of late, his ingenious explanation has received less acceptance.

Another view presumes that the muscle is kept constantly in a state of sensitiveness by contributions of excitation from the spine. Out of the influence of these, *plus* the normal excitability, arises the so-called tone of the muscle. It would be lost by nerve injury, sensory or motor, and by certain central diseases, and with its loss the increment of sensitiveness due to spinal contribution would fail, and with this of course, too, the knee-jerk.

All reinforcements would be explained as coincidently supplying power to these ever-flowing tone waves. Under this explanation, knee-jerk becomes a local muscle-jerk, and its brief time not so surprising or embarrassing. When I last wrote of this matter, we were inclined to accept the tone theory as explanatory of all the facts; but, in the light of Lombard's and Bowditch's work, and my own further reflections, I have come to doubt more and more, and to feel it as possible that knee-jerk is really a peculiar reflex, with a short time. To settle

the matter we require fresh laboratory studies of muscle-muscle reflexes in man.[1]

As regards the tone theory, it seems hard to conceive that instantly on nerve section the muscle should be so toneless as to give no knee-jerk, and there are other opposing facts. Section of the motor nerves through which the tone waves flow (if they exist) paralyzes knee-jerk; but section of sensory nerves does the same, and it is hard to explain this, unless we conceive of the individual muscle metabolisms as furnishing to the spine the essential excitations which return from it to the muscle in the tone waves.

If tone, in the sense here explained, be not a competent theory, then we must consent to call knee-jerk a reflex, and consider all reinforcements as not going beyond the spinal ganglia, and as therein reinforcing reflex excitations, in place of spreading out as tone waves to the muscle, and therein reinforcing.

Tone has been taken to mean tension, or some more mysterious preparation, for response to excito-motor agencies. If it be tension, this ought to be capable of being shown. I spent a great deal of time in efforts to see, if with the leg at an angle and without a blow on the tendon, reinforcements would not show themselves. In this I failed entirely. I do not say it is not to be shown. But if tone waves reach the muscles, and are the positive things they seem to be, they ought to be capable of registration. Certainly they cannot mean tension; and, if not measurable in muscle, it would look as though they did not reach it.

Time may settle this question. Meanwhile, as against reflex theories is the time. As to this, however, it is unwise to be sure that skin-muscle reflex time is the only one. Muscle-muscle reflex time has yet to be more fully

[1] I should then propose to use these terms, muscle-muscle reflex and skin-muscle reflex.

studied, and may be more brief than has been supposed. We were quite unable to reinforce skin-muscle reflexes, such as that of the cremaster. The study was excessively difficult, and I do not yet feel absolutely assured that we were correct. If it should prove that we were, this might be regarded as measurably against the view that the muscle-muscle acts (K.-J.) are true reflexes. At all events there seems to be this difference between the two sets of replies to excitations.

There are other points which look favorable for the reflex theory, or as against tone explanations. Thus, when we cut the motor roots which enable knee-jerk to occur, we cannot restore knee-jerk thus lost by substituting a delicate electric current in the peripheral nerve end to imitate the lost spinal contribution. Again, a blow on the tendon causes not only local, but sometimes also distant reflex muscle acts in the other leg or in an arm. These cannot be skin reflexes,[1] and are seen best in the presence of emotional reinforcements.

Again, it often happens to one to strike a tendon with equal force over and over, and only after a time to get a violent response, far beyond the man's normal. I have seen this in tired men. It appears to be a summation of excitations and an explosive reply. I find it hard to conceive of this as a localized muscle phenomenon. It is like a reflex occurrence. A blow on a muscle elongates a limited breadth of fibre. It contracts, and this is like a knee-tendon jerk, but is a limited and coarse reply. If knee-jerk depended only on perfect extra-spinal muscular excitability, when this quality rises, as it does in some diseases, the knee-jerk ought also to increase, but in these very states it may be lost, and yet, the answer to a blow remain above the normal.

We were never able to reinforce muscle acts electrically caused. As Professor John Curtis suggested to me, this

[1] A blow elsewhere does not cause them.

may be because electricity is a less potent reflex excito-motor than mechanical force. If the reinforcements reach muscle as tone waves, one excitor should be as good as another; but if they do not, then the only agents which will reinforce will be such as competently reach along reflex nerves to the spine, and it would look as if a blow did this, and moderate faradic currents did not.

There is, indeed, already some reason to suppose that mild electric currents are less competent reflex excito-motors than mechanical force. Thus, while a mere touch on the side of the thigh will excite the cremaster reflex, a faradic current strong enough to evoke muscular motion may not cause the testicle to stir.[1] The argument as concerns electricity and mechanical stimulus is emphasized in spastic cases. In these, the faradic electric reactions are usually not increased, while a tap or squeeze or tendon-jerk is competent to excite extensive movement. The blow gives rise to excessive action, the electricity only to common responses.

I have stated the gathering arguments for and against, but after all has been said, we are still in doubt as to the true nature of tendon-jerks. Yet, as the matter now stands, it is more and more clear that the time element is not the convincing argument against considering the knee-jerk a reflex, which many writers have held it to be.

Since Jendrássik's discovery and its extension by Lewis and myself, with our additional discovery of the reinforcement power of sensations, and Lombard's emotion reinforcements, the question of the nature of these has also to be considered.

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[1] To test this place both conductors dry on the excito-cremasteric region. The first cool touch may cause cremaster reflex. Then, being careful not to move the conductors, make and break circuit (faradic). A current powerful enough to excite the muscles will be found up to a certain point comparatively incompetent to occasion reflex stimulation of the cremaster.

There seem to be but two possible ways in which motion, sensation, or emotion can reinforce. One is indirect and one direct. It may be that all motor or sensory activity tends to release from inhibitory control other ganglionic masses than those in immediate use, and sets them in a measure free to respond to other agencies, such as external stimulus. To use a homely comparison, "the brakes are taken off." Thus a motor volitional act may so affect a spinal centre as either to set it at liberty to send out more energetic tone-waves, or more potently to feel, or to feel and reply to reflex excitants. The other view is that every motor act or sensory impression sets free surplus energy, which is felt as reinforcement throughout the body. And this is the doctrine of overflow.

I have already pointed out that every positive and abrupt motion or sensation, however remote and wherever it may be, is able to reinforce any tendon- or muscle-jerk. What is true of the stronger influences must be measurably true of the weaker. The reinforcing excitations may not show in the increase of the jerk, and yet may exist. Accept this quite possible conception that every sensation, every volition, every emotion (perhaps every mentation) sends its excess of force over countless tracks into many parts of the nervous system, and possibly into every muscle. The effort to realize this incessant effluence of energy is difficult. Some attempt at analysis may be of use, and I would also like to point out what are the problems, for the solution of which we must look to the laboratory and clinic. When we will a motion with some positiveness, the knee-jerk is reinforced, and so is the muscle-jerk. This happens whether the muscle called to act exists, or has been lost by amputation, or is above the knee in walking, or below it. If it were only to occur when the muscle is (let us say) in the feet, or below the knee, we might think of the nerve influence as passing through the crural centre, but

a wink does it even better. How then does the efferent force reach the knee-centre? Is it a mere overflow, or is it an inhibitory act releasing the crural centre from cerebral control, and what columns of the spine must in any case rest uninjured to enable it to occur? Also what is the time of this reinforcement?

Then, as to sensations. I pull at a hair on the arm, and get prompt reinforcement of the knee-jerk. In this case does the afferent impression reach the sensorium first, and then affect the knee-jerk? Is the time of motor and sensory additions alike, or how nearly? Does the pinch of a foot influence the knee-jerk as the afferent impression goes up the spine, or does it first reach the sensorium, and act thence downward on the centres finally concerned in the knee-jerk?[1]

Emotions increase the knee-jerk. Do these act so as to set the spinal centres free, or is their influence also one of overflow?

Thus at every step the question of overflow or inhibition faces us, and in disease it is still the same. Certainly in health either explanation seems competent. But in disease and injury this is hardly so. When we cut the cord a state of shock, so called, occurs, that is—the reflexes and the knee-jerk are lost for a varying time. This may be merely exhaustion from a tremendous hyper-physiological excitation. Recovering, the knee-jerk and reflexes get more and more sensitive, and, at last, reach the normal and rise far above it. Why do they go on increasing,

[1] In the case of fractured spine (spoken of later in this lecture), there was every reason to believe the paths from leg to brain, and from brain to leg, were cut off. I examined this case with Prof. Osler, and both were satisfied of the completeness of the isolation. At last, after many blows on the right knee tendon, it began to respond better, and then we found it could be reinforced by a grimace, so that here was a path open from brain to leg. Also, it was not reinforced by a sensation (cold from ice). This seems to be a novel use of reinforcement.

unless the pathological changes at the point divided act as irritative reinforcing foci? Again, in some spastic palsies, the knee-jerk being enormous, it is easily reinforced by winks or hand acts. It is hard here to conceive of the cerebral influence as largely cut off. Indeed it is not. Volition exists and is really good, but not competent because of the rigidity it causes. Generally, in all irritative spinal maladies the knee-jerk rises before destruction of the centre checks it. Also, after section of the cord, inhibition does not explain the gradual increase of excitability, while it is explained by the coming on and increase of inflammation at the lower surface of the section and the sequent changes.

Suppose, now, we can show that one volition reinforces another—*i. e.*, that the tired right hand gains vigor from sudden coinstantaneous use of the left hand. Either this is overflow, or else the willing of motion in the untired left hand must be supposed to relieve the tired centres from inhibition, and thus enable them better to obey the will they are failing to obey. If we accept overflow to explain such volitional reinforcement, there is no reason why we should not do so in regard to knee-jerk reinforcement.

Men who hold theoretic explanations too tightly, are apt nowadays to get sharp lessons. Yet, on the whole, it is often wise to possess some binding explanation of groups of facts. It is helpful in many ways. Possessing no certainty, I most incline, for the present, to look upon all reinforcements as overflows, and to consider all abnormal increase of knee-jerk as the product of irritative lesions. Physiologically, the conception of innumerable effluences of energy, motor, sensory, emotional in endless activity fills us with wonder and tempts one, however we explain them, to speculations remote from the purpose of this lecture.

Before dealing with the little there is to add as to tendon-jerks elsewhere, I desire to allude to the last facts

which have been born of Jendrássik's discovery. My friend Prof. Bowditch, of Harvard, has been studying with care the time of reinforcements. His result is most interesting. I quote, by permission, Dr. Bowditch's brief summary of his paper, which is not yet in print.

"A sudden, brief muscular contraction reinforces the knee-jerk when the latter occurs within a brief interval of time (less than 0.25 second) after the former. With a longer interval the reinforcement gives place to an inhibition. With a still greater length of interval this inhibition disappears, so that when the blow on the tendon follows the muscular contraction with an interval of 1.06 second, the knee-jerk has its normal value. The interesting feature of the result is, to my mind, the evidence of a sort of oscillatory activity, or rather change of irritability in the centres concerned in the knee-jerk. I attach no particular importance to the figures I have given. They will doubtless have to be changed when more observations are accumulated. It would be interesting if this period of oscillation of the nerve centres should be found to differ in different persons, after the manner of the personal equation of astronomers."

This discovery that a sudden brief reinforcement first increases knee-jerk and then lessens it for a brief season is curious. The latter may be read as a brief expression of fatigue in the centre, or as interference of nerve waves; coincidence with increase, interference with decrease of knee-jerk.

Let us now turn again to the muscle-jerk. When a blow falls on a muscle, is the response purely the answer of intrinsic muscular irritability? This is a question which so far seems not to have been asked. The muscle shortens when struck, even though without spinal connections; but as I have already said, it may be that so long as these are whole, muscle-jerk may be like knee-jerk, and profit by spinal contributions to its coarser phenomenon. If it be a double phenomenon, its curve

should show this fact and exhibit a double ascent, since the time of the muscle-jerk and its spinal addition cannot be one.[1] If the whole matter is but a response from a toned muscle, then we should have but a single curve.

The direct muscle-jerk must be familiar to all the observant among you, as seen easily when the percussion hammer strikes on the thin chest walls and instantly the pectoralis fibres, for about the width struck, contract from end to end. They have been violently pulled upon by the indenting hammer; a coarse, powerful excitation. You observe their responsive contraction. Next, at the point struck, you see a small hump quite slowly form and as slowly disappear. The first phenomenon you can see in all muscles more or less well; the second is not so easily obtainable. As concerns the first, it varies as do tendon-jerks. It is reinforcible and obeys the same laws as these do. In the muscle backed by bone, as on the chest or over the scapula, it is well exhibited; but also in other muscles it is well shown. The arm muscles are especially sensitive, and it is possible to pick out muscles as we do with electricity.

In the leg it is more difficult to get as good responses, except in thin people; and here, as elsewhere, we get exaggerated effects, near to the "nerve-points" of Ziemssen. To get the best results slight extension is needed. The pull on a length of muscle can only be had when the tissues are so mechanically stretched as to enable a blow to pull sharply on a length of fibres. Extreme tension lessens the response. In the feeble, and in the tubercular, the direct muscle-jerk is best. Partly, this is due to the great effect of blows on uncushioned muscles. Partly it is, I suspect, physiological, but whether from increase of intrinsic excitability, or from spinal con-

[1] This is, of course, if the knee-jerk and measurably the muscle-jerk be reflexes.

tributions is not known. In some diseases, as in ataxia, it increases.[1]

The hump which slowly rises at a right angle to the longer rise of a length of fibres is the direct effect of the impact. Over muscles backed by bone we get it best, in either health or disease. It is in its larger expression and where found in other muscles than those mentioned, more or less, a sign or an accompaniment of feebleness. If we kill an animal, this response to a blow increases for a time, and in some diseases, with nervously isolated parts, is increased. Stokes mentioned it about 1848, and I experimented and wrote upon it in 1858; and often since it comes up as a re-discovery.

In section of the spine, or fracture with like result, the muscle changes are curious. I show you an illustration from one of Dr. Osler's cases: here is a fracture of the spine, at the ninth dorsal vertebra. It took place early in April, 1888. There is as you see, no sensation for pain. Pin pricks do not bleed, for this is not, as described, to be found only in hysterical anæsthesia. There is no voluntary motion.

I strike the leg-muscle anywhere, it moves better than usual in its length, but, also, the local hump is huge. I never before saw it so remarkable. Even a pinch causes it. The observation is to me a novel one. And observe that there is a spot of local gangrene on the heel. Some undamaged ganglia exist below the seat of injury, or we would not have even the faint knee-jerk seen after several blows on the right tendon. What is the reason for the peculiar irritability to a blow? Electrical tests show, I am told, no remarkable degenerative reaction. Possibly there may be an increase of muscular irritability from chemical irritative changes in the muscle, but the whole subject awaits more careful study.

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[1] Buzzard first pointed this out in an admirable article on knee-jerk, from which some of my arguments are taken.

In practice we have to deal only with ankle-jerk, knee-jerk, and biceps-jerk, and chiefly with the latter as a means of learning when certain spinal maladies are invading the arms. As concerns biceps-jerk, I hear men complain that they cannot get it. Let the patient rest the bared limb on the arm of the chair in which he sits. The operator feels for the insertion of the biceps tendon; puts on it a finger and strikes upon that, thus. He at once feels in the finger the muscular response. In thin persons a blow directly upon the tendon causes the arm to jerk visibly. Sometimes I put on the tendon a bit of caoutchouc, and strike on this firm cushion.

Pray attend to the fact that the biceps tendon, like the knee-cap tendon, must be stretched to enable us to influence the attached muscle. Elbow-jerk is certainly less easy to get than knee-jerk, but it is worth looking for, and is often a valuable aid to prognosis.

While much care is apt to be given to the presence of clonus, a symptom only as a rule present in excess in disease, the normal expression of it, ankle-jerk is, I fancy, less sedulously studied. The usual mode of evolving ankle-jerk is to strike a smart blow on the stretched tendo Achillis. The patient being seated, or supine, take up the foot in the left hand and flex it so as to make slightly tense the tendon on which you strike, and preferably with the hammer. If there be no response, flex the leg slightly and repeat the blow. The reaction of the muscle is felt by the hand which holds the foot. To show it better, I loop a thin rubber band over the tip of the sole, and with it make a slight extension. As now I strike, you see the foot move because of the contraction of the abruptly stretched gastrocnemius. I take another case, and show you another method which I do not see elsewhere used. It seems to be new. With the foot as before, I strike on the sole of the foot. This, also, acts so as to make a quick pull through the tendon on the muscle. It is less awkward than the blow on the tendon, and shows best with the

boot or shoe on the foot. In the books you will see mentioned what Gower calls the "front tap," which now I show you. The foot being flexed, we strike a blow on the anterior muscle, or with less effect on the tibia. You see that the foot moves, showing that the calf muscles have acted. Gower mentions this as seen when the phenomena are in excess, but, as a fact, this reaction is common enough in the healthy, if the blow be given near the ankle. I believe that the front tap phenomenon has been sometimes considered as positive evidence of organic disease of the cord. As I now show it to you, it is strongly marked in spastic disorders, and more mildly expressed in some well people, or in neurasthenics.

And now as to clonus. It is easy to illustrate, but, in some cases, needs a little care to develop. To get it, I place the subject (a well man) so as to have the knee a little bent, then I suddenly flex the foot. You see I get no answering motion. This is because the flexion so made is not abrupt enough to secure even a single reply, for, remember, a sharp blow on the tendon or sole does usually secure this in health. In a spastic case, like this boy, who has Pott's disease, the apparatus involved is excitable enough to go on responding so long as I keep up flexion of the foot.

See what happens. I push up the foot and the stretched muscle moves the foot. My continuous pressure once more stretches the muscle. Again it moves, and so on, till the power to reply is exhausted. We may substitute a weight, or an elastic attachment, for the hand and see the motion continue for an hour or more. Here is a set of curves written by causing the foot to record its motion on a moving sheet of smoked paper. A second marker notes the time. You see the clonus is seven to the second. It varies from five to nine, and the time of the two feet taken together varies a little. It causes no fatigue, although moving for an hour at the rate of 420 to the minute.

In milder cases it ceases after a few movements, but we never see clonus continuous and energetic save in true spastic cases. In milder examples, as in hysteria and neurasthenia, we must consider it as to amount and vigor, and as to its presence with other symptoms. I now speak of what you get by using the hand alone, and keeping up pressure. You may sometimes, though rarely, get it in a mild form in health—that is, in place of a single response to the blow on foot or tendon, two to six, such motions occur, each slighter than the last. There is, of course, in all this a vast amount of physiological interest upon which I have dealt but slightly.

I come now to say what amount of practical use we can get out of the varied phenomena I have described. Keep clearly in mind that if you find a tendon-jerk lessened or extinct you must try if it can be revived or increased by motor or sensory reinforcements. Absence is most suspicious, but do not let this alone make you decide that you are in the presence of coarse spinal lesions. I know two ideally healthy people, who have no knee-jerk, ankle-, or biceps-jerks; no reinforcements. Both have direct muscle-jerk, non-reinforcible. Explain this, I cannot. I cannot even guess at an approach to an explanation, but it is enough to make one careful. Taken alone, this negative sign has little value. It usually means, when present with other suspicious signs, that the nerve loop from muscle to spine, and back to muscle—*i. e.*, the muscle-muscle loop—is damaged in the spinal centre, in the nerve loop afferent or efferent. It may mean, also, that the muscle has itself lost power to respond. To know what has suffered, we must appeal to other symptoms. It tells us that something is wrong, but not what is wrong. Thus it lessens, and at last is lost in posterior sclerosis, and in sclerosis of the gray anterior columns, and also in hypertrophic muscular palsy, thus affording illustrations of loss of knee-jerk from disease of

either the sensory or motor columns, or the muscular mass. I do not see that, as yet, we have got out of the knee-jerk changes all that we may yet hope to win. Except in locomotor ataxis, and in the early recognition of spastic states of the cord, it has little direct practical usefulness. But it has a negative value, and a great one, owing to its remarkable sensitiveness. Let us deal first with its negative utility.

It is a common case to see, nowadays, a man of thirty, free from constitutional taint, or with a doubtful history, ruddy, and well nourished. Otherwise he is easily tired, and this may apply to body and mind, spine and brain, or to either. He has fugitive numbness of the extremities and ache in the cervical or lumbar spine. Beyond this he has no spinal symptoms, and his knee-jerk, ankle-jerk, and elbow-jerk are perfect. You may be sure that he has merely neurasthenia. But if he be very emotional, and this exaggerates his tendon-jerks, and even causes slight clonus, you may have to wait long, and be careful in order to get undisturbed results. It is an every-day experience that in suspicious cases integrity of tendon-jerks helps us to clear views. It is quite certain that some cases of posterior sclerosis begin with excessive knee-jerks, which by and by fail, and at last disappear. For a time they can be recalled by reinforcements, but, sooner or later, are lost altogether.

An interesting case of ataxia of the arms with nearly normal legs was recently in our wards. I use it here to illustrate the history of tendon muscle-jerks in ataxia, and also to call attention to the way in which we state with brevity such phenomena.

Modern note-taking is so elaborate that whatever rationally shortens its method is a pure gain. Let me point out how you can record these phenomena briefly in a sort of equation, and refer you to the paper by Dr. Lewis and myself for fuller statements.

I give below a sufficiently full explanation of the abbreviations:

Arms: R. E. J. o. Rt. o. L. E. J. o. Rt. o.
R. M. J. + +. Rt. o. L. M. J. +. Rt. o.

Legs: R. K. J. 25°. Rt. 40°. L. K. J. 27°. Rt. 36°.
R. M. J. quadriceps, n. Rt. n. L. M. J. n. Rt. n.

Station: $\frac{2}{A}$, $\frac{1\frac{1}{2}}{D}$. Eyes shut.

Explanation.—Arms: Right elbow-jerk, none. Reinforcement, none, etc. Right muscle-jerk, excessive. No reinforcement, etc. Legs: Right knee-jerk, 25 degrees Lombard's meter. Reinforcement sends lever to 40 degrees, and these records mean maximum of several trials. As concerns muscle-jerk, n means normal, + excessive, and — less than normal. Station $\frac{2}{A}$, $\frac{1\frac{1}{2}}{D}$, means the anterior sway is 2 inches, and the dextral $1\frac{1}{2}$.

Of course, in the not rare examples of posterior sclerosis with lateral column involvement and spastic gait, there is exaggerated knee-jerk, but also, I am sure, as I have said, that excess of knee-jerk may exist in the preataxic stage of unadulterated disease of the posterior columns.

As Lewis and I have urged, it is in the arms of men who have ataxic legs and no knee-jerk that we can follow the whole series from the normal to lost elbow-jerk. And so also muscle-jerk +, with + reinforcements through to loss of all but intrinsic muscle-jerk. I saw, to-day, an ataxic man. He has knee-jerk o. Reinforcements o. Arms, elbow-jerk and reinforcements + +, and muscle-jerk and reinforcements + +. He has no ataxia of arms, but the faintest traces of occasional numbness in the finger-tips. With shut eyes he falls.

I believe that attention has not been called to the fact that, now and then, in diseases a blow on the patellar

tendon causes response in but a part of the biceps mass. I saw this lately in a case of partial destruction of a segment of dorsal cord. For several days, only the vastus internus seemed to act, and that feebly. My colleague, Dr. Sinkler, has made a similar observation recently in a case of syphilis of the dorsal cord. Only the external vastus responded.

I cannot enough warn you against regarding even entire loss of knee-jerk as always a grave matter. At the same time, it is a sign not to be neglected. The sensitiveness of knee jerk, its delicacy, makes it valuable. But illustrations are better than mere general statements. I saw last week a case of mild non-febrile muscular rheumatism. The patient was in bed and under daily use of sixty grains of salicylate of soda. For a week or more he had much lessened right knee-jerk, and none on the left, and no reinforcement. It came back a few days later. The cause of the loss I do not know.

Again, a case of frank meningitis in a lad of sixteen was rapidly relieved. The knee-jerks were good—rather excessive. About the fourteenth day a dull, but very painful ache in the lower dorsal region came on, chiefly on the left side. There was, also, at this time, a sudden albuminuria without signs of congestion. I was not secure as to the cause of the ache, until I observed entire loss of left knee-jerk. I then felt pretty certain that the pain was due to a new focus of meningitis. There was little else to help me, for all through there had been slight pricking sensations in the feet, and this did not largely increase with the coming of the dorsal ache. I next observed, with interest, that while the left knee-jerk was gone there was excess of left foot-jerk from a blow on the sole, and even slight clonus.

There are many disorders, some maladies, and certain normal conditions in which we meet with increase of knee-jerk and ankle-jerk, or even presence of faint clonus. Of some of these I have already spoken. Only

the hasty, or the unwary, could be taken in by the excess of knee-jerk, or the slight clonus of neurasthenia or hysteria. Care will, however, be needed, because it is in these very cases that emotional reinforcements are most violent, and because, also, we now and then meet with incipient spastic palsies, in which there are associated hysteric or neurasthenic states.

There are, of course, many forms of disease which give rise to spastic paraplegia, and in some of them, the earliest distinct warning is to be found in the increased knee- and ankle-jerk. This is especially the case in some of the insidious forms of syphilis, which seem, by preference, to affect the lateral colums of the spinal cord. In the absence of other symptoms which help to reveal improvement, diminishing knee-jerk in spastic disease becomes a valuable index of the change for the better in the disease which at first caused its increase. In the future. Dr. Lombard's meter or my simpler one will be of great value as giving us reasonably precise records of knee-jerk.

I have limited myself, in this lecture, to tendon-jerks and muscle-jerks in chronic neural maladies. A not uninteresting, and a little explored subject, is the study of these in acute diseases. I have said least of ankle-clonus, because, this winter, clonus in general has been the subject of careful experimental study by Dr. Morris Lewis and myself. Our paper will shortly appear.